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# Edible insects – history, characteristics, benefits, risks and future prospects for use

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**Abstract:** The growing global food crisis and the changing climatic and agro-ecological conditions on the planet are predominant, serious, and growing issues that require Global attention. Insecurity caused by the lack of food can have devastating effects on health, with malnutrition being considered a major cause of infant mortality. In addition, malnutrition at an early age has been linked to problems later, including hypertension, diabetes, and cardiovascular diseases. Insecurity caused by the lack of food contributes to lowering immune function and altering the intestinal microbiome. By 2030, the annual economic cost of mortality and noncommunicable illnesses is anticipated to exceed $1.3 trillion. Edible insects are employed in gastronomy and the food industry in many Asian, Oceanian, African, and Latin American countries. Due to cultural preconceptions and disinformation regarding its detrimental characteristics and effects on the human body, Western societies perceive it as animal feed rather than human food. Academic, industrial, and government forces are constantly trying to reduce negative insect perceptions by raising public awareness of the need to find alternative food sources, developing new insect processing methods, and highlighting the health benefits of insect consumption. Insect consumption, also known as entomophagy, has been reported for a long time. It is estimated that roughly 2 billion individuals ingest insects regularly worldwide. There are about 2,000 edible bug species in the literature, the majority of which come from tropical nations. The most regularly ingested insects are beetles, bees, wasps, ants, caterpillars, grasshoppers, crickets, cicadas, termites, dragonflies, and flies. This review covers current insect trends as a prospective food source (alternative food source), describes the benefits and risks associated with their ingestion, and highlights the numerous areas where they could be used.

## Introduction

Food and agricultural systems are currently heavily influenced by factors that threaten their long-term viability. Growing populations and incomes increase food demand, which influences changes in people's dietary preferences. Poverty, inequality, and unemployment impede access to food and obstruct progress toward food security and nutrition goals. Increased scarcity and diminishing soil quality, water supplies, and insufficient investment in sustainable agriculture limit agricultural production. While agriculture contributes enormous volumes of greenhouse gases, climate change has an increasingly negative impact on rural incomes and livelihoods (FAO, 2018). The global increase in meat demand, combined with the limited amount of agricultural land accessible, is encouraging the quest for alternate protein sources. The issue of meat sustainability is beginning to be questioned. Edible insects are appealing as a protein source for human nutrition and animal feed because of their low greenhouse gas emissions, feed ration variety, minimal land use, and capacity to transform low-nutrient by-products into nutritionally complete protein products. About 2,000 species are widely ingested, particularly in tropical places (Huis, 2016). Insect ingestion is not a new concept; it occurs all across the world, although it is still uncommon in Europe. Why not try eating insects? Is it really worth it? The answer is simple: absolutely. Entomophagy has many benefits: insects are high in protein, healthy fats, and antioxidant sub-

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stances. Microelements, particularly calcium, iron, zinc, and vitamins, are abundant in certain species. Insect farming is more environmentally benign than most animals since it produces fewer greenhouse gases and ammonia. When compared to animals, it takes less area, feed, and water to breed (Fig. 1). Insect breeding can be simple or complex, depending on the amount of money invested. These data highlight insects as an important food source in response to mounting concerns about the future, especially from a global food security viewpoint (Zieliska et al., 2018; Kim et al., 2019).

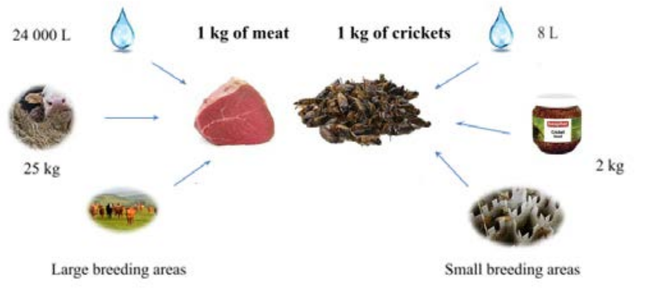


**Figure 1.Comparative balance of inputs/outputs in beef and cricket production adjusted according to Guiné et al., 2021).**

Traditional uses of edible insects as food vary greatly around the globe. When taken with current views of insects as part of the solution to feed the world's growing population, these wide disparities between countries present intriguing questions. If cultures change their food consumption habits and enrich their diets with new foods, conventions and traditions must be formed, which can substantially transform a largely entomophobic society into an entomophilic society. According to history, aversion to particular components can be overcome (Anankware et al., 2021; Svanberg and Berggren, 2021).

Those who practice entomophagy view insects as a delicacy rather than a "endured" diet in times of need. Grasshoppers, for example, are thought to have been favoured among the ancient Near East's social elite. Several bug species have been detected in human coprolites, it is becoming increasingly obvious that entomophagy played a vital role in delivering sustenance during hominin evolution (Anankware et al., 2021).

The European Union has committed itself to move to a more sustainable and resilient food system as part of the European Green Agreement, and following the Covid-19 epidemic, insects could offer a greener alternative to future animal protein production. Legislation The EU is intensively addressing the entomophagous expansion from a specialist novelty to a serious commercial and culinary food perspective for the consumer, with expected legislative permits. The EU Regulation covers insects on novel foods, which are food products that were "not consumed significantly" in the EU before 1997 and must be safe and properly labeled if they are to be placed on the market.

A scientific opinion was issued by the European Food Safety Authority (EFSA) at the end of 2020 assessing the safety of the insect larva *Tenebrio molitor*, also known as the "flour worm". Insects should be eaten in dried form as a "snack" or in powder form as various foods' ingredients. EFSA considers the novel food to be safe for its intended use. The scientific opinion was published in the EFSA Journal, where all accepted EFSA scientific outputs and opinions are available (MPRV, SR 2021).

Several adjustments are required to transition a dominant entomophobic society into an entomophilic society, and these changes must work separately as well as jointly. Above all, food standard and endurance are required when launching a new sort of cuisine. Nutritional adequacy, cultural acceptability, and human dignity are part of the food standard. The establishment or introduction of new food is accomplished when these three criteria are completed and the infrastructure required to maintain the food standard is built. Change's nature and methods can be described in various ways; for debate, they can be categorized into four major categories: 1) laws and regulations, 2) social impact, 3) insects suitable for consumption, and 4) biological and sociocultural aspects in humans. The tradition of eating insects plays an essential part in all of these categories (Fig. 2).

When prominent parties help make the required changes, changing society from entomophobic to entomophilic will be effective. The EU's government, research institutions, and businesses gradually change people's opinions and establish a stable consumer base for insect food products. This transformation of an entomophobic country demonstrates that such social shifts in attitudes are possible, indicating that there are prospects for large-scale human behaviour change in a short period, and providing optimism for future efforts to develop sustainable and safe food systems (FAO, 2018; Svanberg and Berggren, 2021).

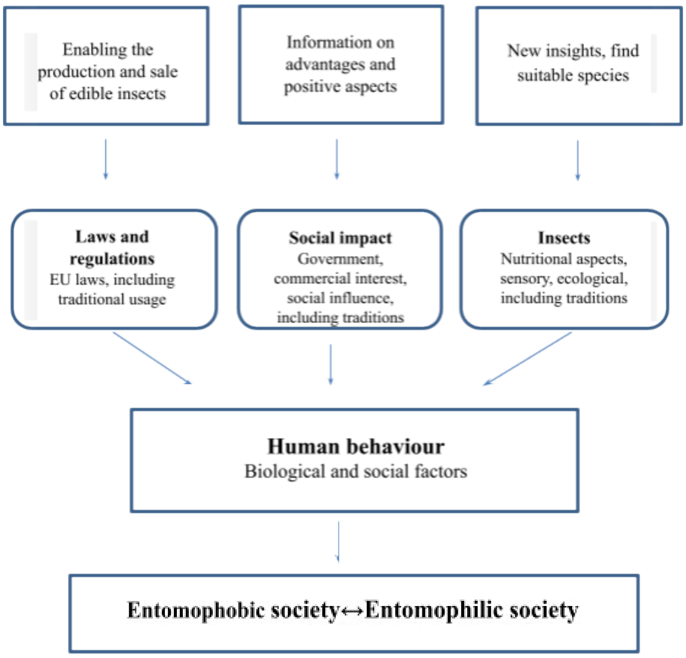


**Figure 2. Factors influencing society's behaviour in the transition from entomophobic to entomophilic (traditional use of insects plays a key part in this position) (scheme based on Svanberg and Berggren, 2021).**

## History of insect consumption

Insect consumption has a long history - the prehistoric people who evolved from modern humans (in Africa in a tropical environment) used insects as food, as evidenced by coproliths. Early hominids gradually migrated to various geographical areas, some of which reached a temperate climate, where there was a shortage of edible plant material and fruit (and related insects). This necessitated broadening their food horizons and including additional animal resources in their diet. People benefited from the freedom that genetically programmed taste preferences and the digestive system allowed them. And it was because of this genetic diversity, they were able to broaden their feeding experience and range in ecologically different regions and ecosystems. Although our ancestors' intrinsic preference for sweet foods has not vanished, views about insects may have shifted from perceiving them as a valuable food to viewing them as hazardous as they began to focus their food choices on larger fat-rich species. However, more historical research is needed to support this hypothesis. Nonetheless, evidence suggests that in Roman times, fat-rich wood-destroying larvae, collectively called *"cossus"*, were used in gastronomy, as evidenced by recipes for various dishes from Germany 200 years ago. It is apparent that, especially in Western civilizations, the growing image of insects as disease vectors, the link of insects with dirt and death, witchcraft, and poverty has likely resulted in increased estrangement and dread of insects as sustenance. Although grasshoppers are mentioned in the Bible as a food source, they are frequently disregarded. In Sardinia, the consumption of worms ('*Casu marzu*') was well-known, in Germany, it was mite cheese ('*Milbenkäse*'), in Finland, children in particular consumed bumblebees because of their sweet taste (they sucked the sweet nectar out of them after killing them) (Halloran et al., 2018). There is also evidence that people ate cockroaches (*Melolontha*), especially during the famine in certain areas of Romania, Italy, and Ireland. There is even a well-known habit of eating lice (*Pediculus humanus capitis*) in many cultures outside of Europe. Salted resp and smoked grasshoppers were consumed by people in some parts of Russia and Crimea until the 19$^{th}$ century. During the 19$^{th}$ century, grasshoppers were consumed in southern France. Moldovan people consumed adult chafers (*Amphimallon pini Ol.*), and farmers in Lombardy consumed beetles (*Rhizotrogus assimilis*). Ivy galls (*Glechoma hederacea* L.), which produce Cynips insect species, were consumed in France. In Crete, the inhabitants liked the juicy galls of sage (*Salvia* sp.). They collected them in early May and were even a major trade item in the eastern Mediterranean. The aromatic and acidic taste of the galls produced by the insects *Aulax* sp. were valued. Children in the historical-geographical region of Carnia in north-eastern Italy had a local custom of eating sweet flying moles from the Zygaena and Amata families (Zagrobelny et al., 2009). Hungarian children ate the stomachs of black *Xylocopa* sp. and collected a tasty paste from *Hoplitis adunca* solitary bees' cane nests (Ulicsni, Svanberg, and Molnár, 2016 ; Svanberg and Berggren, 2021). In Slovakia, there is no historical practice of eating insects. However, it is reported that it is done in some locations. Nádaská (2016) used ant larvae as a substitute for real caviar.

## Consumption of insects in the present

Although insect consumption in Europe is limited mainly by social prejudices, edible insects are commonly used worldwide (Fig. 3). Canned silkworm pupae are sold in Korean grocery stores and prepared into delicacies. In rural regions, grasshoppers (*Oxya velox*) are also used. Fried grasshoppers with soy sauce are popular in Japan (the dish is called inago). Larvae and adult bees or wasps are also considered delicacies in this area. They can be consumed raw, cooked in soy sauce, or served with rice. In China, entomophagy has been practiced for almost 2,000 years (Kim et al., 2019).

Eri silkworm pupae (Samia ricini) are a delicacy in Northeast India (Peigler, 1993). In Thailand, insects provide a significant amount of protein, fat, and other nutrients. Residents in the village of Ubon ingest 20–60g of insects every day (Sungpuag and Puwastien, 1983). The Thai Ministry of Public Health recommends consuming insects to obtain the necessary nutrients. In Papua New Guinea, the Red Palm Weevil (*Rhynchophorus ferrugineus*) is a popular culinary insect. In some areas, grasshoppers, crickets, mole crickets, praying mantids, and spiders are also eaten (Kim et al., 2019). Although entomophagy is uncommon among European immigrants in Australia, the market for edible insects has exploded, and edible insects may now be found in some eateries. In Africa, insects play a significant role now and from a historical perspective. The most popular insects are caterpillars and termites, however, other bug species are also eaten (Kelemu et al., 2015). In Uganda, grasshoppers are used as a source of energy and protein. More than 65 species of insects are consumed in Congo, and edible insects account for more than 20% of the animal protein generated (De Foliart, 1999). Edible insects are a key source of protein in America, particularly among Amazon tribes. They consume mainly representatives of *Rhynchophorus*, also ants and larvae. In Mexico, edible insects are a tradition that is consumed in both rural and urban areas. Following the invasion by the Spaniards, towns began to become more westernized, limiting entomophagy to rural areas.

Nonetheless, escamol is frequently served in Mexican restaurants, a dish made from fried insects and aromatic spices. The Yukpa people of Colombia enjoy insects. However, they have been forced to curtail their bug-eating due to severe deforestation (Kim et al., 2019).


**Figure 3.Insects are used as food in various places (FAO, 2018).**

## Benefits of insect consumption

Insect nutrition varies depending on their food, developmental stage, sex, species, and growth habitat (Kim et al., 2019). On the other hand, Insects are extraordinarily high in proteins, lipids, and vitamins, according to scientists (Rumpold and Schluter, 2013). Edible insects have a protein composition of 35 to 60 percent dry matter on average (Schlüter et al., 2017), greater than plant sources like cereals and legumes. Mlek et al., (2014) found that insects give even more protein than meat and eggs in the upper range. Crickets and grasshoppers, in particular, are high in protein.

Due to a hard exoskeleton, the digestion of insect proteins varies greatly. Chitin-rich exoskeletons are extremely tough to break down. It is unknown whether or not humans can digest chitin (Muzzarelli et al., 2012). However, human gastric secretions include enzymes that break down chitin, suggesting that the human body may be capable of doing so (Paoletti et al., 2007). As a result, the exoskeleton is frequently removed before the edible insects are treated. According to scientific studies, insect proteins without an exoskeleton are 77-98 percent digestible (Kim et al., 2019). Some species lack or have lower methionine, cysteine, and tryptophan levels in terms of amino acid concentration. As a result, a well-balanced diet is essential, with insects serving as a dietary supplement. According to the WHO, insects generally meet the requirements for critical amino acids because most species can offer a sufficient number of essential amino acids (isoleucine, leucine, lysine, phenylalanine, threonine, valine, arginine, histidine, and tyrosine).

Compared to other insect species, Blattodea (cockroaches) are high in lysine, valine, methionine, arginine, and tyrosine. Beetles have a greater leucine content than other insects.

Insect larvae are a better supply of amino acids than adult insects, notably arginine, which boosts the immune system and aids the heart and blood vessels. Cockroach larvae, for example, have twice the arginine content of beef and pig (Tang et al., 2019). Fat is the second most essential component of insects in terms of nutrition. Various factors, such as gender, reproductive stage, season, diet, and habitat together affect the fat content of edible insects.

Gender, reproductive stage, season, diet, and habitat all impact the fat content of edible insects. The fat content ranges from 13 to 33 percent on average.

Larvae and pupae have more fat than adult insects; a higher fat content also characterizes females compared to males (Mlček et al., 2014). Insect fatty acid profiles also depend on species and food - but unsaturated fatty acids generally predominate. Ants, bees and wasps contain about 42% saturated fatty acids, and termites contain an average of 35% saturated fatty acids. Palmitic and stearic acids are the most abundant saturated acids, while oleic and linoleic acids are the most abundant unsaturated fatty acids. The *Orthoptera* order is especially rich in linoleic acid. Lepidoptera (butterflies) have high quantities of linolenic acid, identified as a possible brain and spinal cord protection nutraceutical (Tang et al., 2019).

Edible insects are high in vitamins (particularly A, B1–12, C, D, E, and K) and minerals (iron, manganese, phosphorus, magnesium, potassium, sodium, selenium and zinc). Vitamins B1, B2, and B6 are particularly abundant in caterpillars (Rumpold and Schluter, 2013). Vitamins A, D, and C are abundant in bee larvae (Finke, 2005). *Rhynchophorus ferrugineus*, the Red Palm Weevil, is known for its high vitamin E concentration. The larvae of houseflies and grasshoppers are especially rich in calcium. Bees and grasshoppers are extremely rich in potassium. Iron is found in higher concentrations in all edi-ble insect species than in fresh beef (Tang et al., 2019). Pal and Roy (2014) state that the maximum iron content of ~35 g/100 g of dry matter is found in termites and caterpillars. Calories obtained from insects reach up to 776.9 kcal / 100 g of insects, often exceeding soy, corn, and beef (Ramos-Elorduy, 2008).

## Risks associated with insect consumption

Despite the apparent nutritional value of edible insects, food safety concerns such as microbe levels, allergic reactions, and toxicity can all represent possible health risks. Insects can also spread biological and chemical toxins, posing a health risk to consumers. These food safety concerns are linked to insect ingestion, either directly or indirectly (through the animal feed). Harvested insects can be difficult to disinfect due to their small size, contributing to contamination inside the manufacturing and processing system. The source of edible insects is a significant consideration; insects raised in a sanitary environment are safer than insects caught in the wild. Murefu and colleagues, 2019; FAO, 2021).

## Insect use perspective

Firstly, insects are considered a low-cost source of food. Resources from free harvest from nature are almost free, and breeding species usually feed on economically advantageous feeds with efficient energy transfer. Consumption of carbon and water and ammonia emissions are lower in farmed edible insects than animal farming (Halloran et al., 2016). Insects' life cycles are often much shorter than those of other protein sources, requiring less breeding space. In contrast to low costs, they are often sold at high prices in the market, which brings promising income opportunities worldwide (Guiné et al., 2021). Establishing an edible insect farm does not require significantly high start-up capital. Currently, most insect farms exist in India and Southeast Asia. However, insect farms are beginning to be built around the world, which will significantly impact agriculture - increasing employment opportunities, increasing incomes, and reducing the consumption of pesticides and herbicides. In the gastronomy and food industry, insects can be used to prepare new healthy and tasty meals, value-added foods, and innovative foods. Edible insects can also be an important part of gastronomic and culinary events. Insect-isolated bioactive substances can be utilised efficiently in medicine to treat various diseases and in the pharmaceutical industry as a part of medicaments. These substances could also be used in the cosmetics industry. By-products (exoskeletons) can be effectively used as a source of fertilizers, materials for the production of eco-packaging,

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etc. Last but not least, insects can also be used to a much greater extent in livestock farming (Fig. 4).

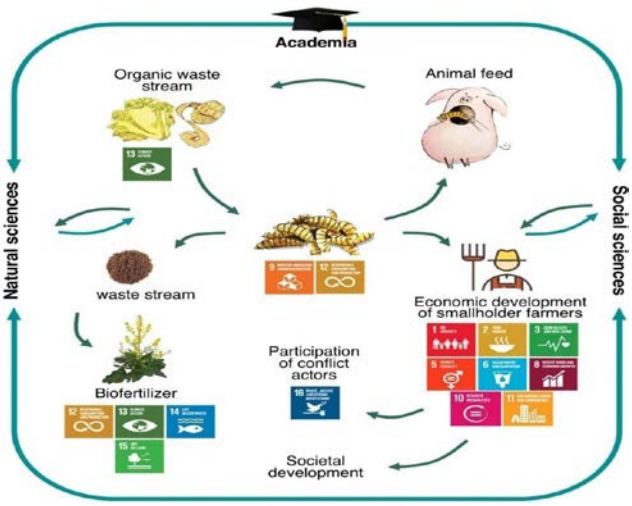


**Figure 4. Perspective associated with the use of edible insects (adapted from Barragán-Fonseca et al., 2020).**

## Conclusion

According to historical records, insects were a common element of the diet in many places of the world. However, it has been considered a marginal food in Europe, and its use varies between EU countries. Nonetheless, surveys conducted in numerous nations point to an increasing interest in consuming edible insects. It is beginning to be perceived as the future food with great potential for various industries. However, this indicates that laws will be needed to allow people to consume insects and that practical aspects of insect farming will need to be developed. Promotion and awareness will also be important as significant factors in changing a society that is now largely entomophobic to entomophilic. Edible insects rich in biologically active substances can be used in gastronomy to prepare healthy and tasty meals and develop food culture. With a growing global population, it can help utilize sustainable natural resources, and the area of medical and pharmacological use is also significant.

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